

Risk factors in scrotal epithelioma¹

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Since the account by Percivall Pott (1775) of scrotal cancer in English chimney-sweeps, epidemics of this disease have occurred in paraffin and tar workers (Volkmann 1874), shale oil workers (Bell 1876, Scott 1923), mule spinners in the Lancashire cotton trade (Wilson 1910, Southam & Wilson 1922) and machine tool setters and operators (Cruickshank & Squire 1950, Thony & Thony 1970). The reviews by Butlin (1892*a, b*), Henry (1946, 1950) and Kipling (1974) give informative accounts of these outbreaks. In each of these industries, except engineering, improved technology or the actual decline of the industry itself have led to a reduction in the number of men being affected. In 1965, Doll *et al.* published an important cohort study based on the workers in the British gas industry, which demonstrated the hazards of tar products and noted three fatal cases of scrotal cancer as well as increased incidences of lung and bladder cancer. In the accompanying paper by Lawther *et al.* (1965), there is an interesting description of the conditions in which the men worked, and the level of polycyclic aromatic hydrocarbons in the fumes above the retorts was investigated quantitatively. The maximum concentration of 3,4-benzpyrene was 2330 µg/m³ of air to which the 'top-men' were exposed. Natural gas has now replaced this industry and so once again a hazard has disappeared. Only 61 new cases of scrotal cancer were notified in 1970 to the Cancer Registers of England and Wales (OPCS 1975), and in the years 1963–66 a higher incidence was found in the Midland and North West regions (OPCS 1972).

Six cases of squamous cell carcinoma of the scrotum have occurred since 1955 in a Manchester factory, in which about 1200 hourly-paid men are engaged in precision light-engineering techniques, using mild steel as the raw material and both neat cutting oils and soluble oil emulsions as coolants. Bar automatic lathes are widely used in the factory. Solvent refined cutting oils have been used extensively since 1968. The general cleanliness and opportunities for hygiene in the factory may be fairly claimed as being above average for this industry. Details of the five fatal cases are summarized in Table 1; in all of these cases histological examination showed squamous cell carcinoma.

In the sixth case, three scrotal lesions have been found at different times since 1973 in an auto-setter who entered the factory in 1955 after twenty years as a mule spinner in a cotton mill. His lesions have all been treated by excision biopsy and histologically were squamous cell carcinoma-in-situ and noninvasive carcinoma. This employee, now aged 62, remains alive and well in August 1978 and attends for examination every three months. In addition to these cases of scrotal disease, 10 men have been found who have developed premalignant keratoses due to exposure to mineral oil on their forearms (Table 2). These men need to be regarded as having a higher risk of developing a subsequent scrotal cancer. They were all seen by consultant dermatologists who diagnosed the lesions clinically as keratoses due to oil and they

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Table 1. Details of 5 fatal cases of scrotal cancer (1955-75)

Employee	Year of entry into factory	Year of death	Age at death (years)	No. of years of service	Main occupation	Notes
W G	1927	1955	54	28	Auto-assistant	
H W (brother of P W)	1951	1968	44	17	Tradesman turner	11 years previous work as capstan lathe operator
L W	1950	1973	56	23	Auto-setter	
J A S	1936	1974	56	38	Auto-setter	Developed keratoses on forearm in 1969
P W (brother of H W)	1949	1975	61	26	Machine setter	Refused offer of examination by Works MO in February 1973

Table 2. Details of forearm keratosis cases

Name	Year of birth	Year of engagement	Occupation	Notes
C C	1912	1949	Auto-setter	
W H	1921	1939	Chargehand auto-setter	
L H	1919	1945	Auto-setter	
L N	1922	1945	Auto-setter	
J J	1912	1944	Auto-setter	
H D	1917	1931	Auto-setter	
J W	1912	1949	Scrap handling	Died from bronchitis in 1975
J S	1915	1956	Auto-setter	
D R	1910	1950	Chargehand auto-setter	Mule spinner for 11 years
S D	1914	1948	Auto-setter	

were treated by diathermy, curettage or excision. Two cases were reported histologically as squamous cell carcinoma-in-situ.

Preventive measures

Various measures are being taken in this factory to avoid further serious cases. In 1972, routine medical examinations were offered to all men with more than 15 years service in contact with oil-based coolants, and this was later extended to those with 9 or more years service. Initially 65% volunteered and this was improved to 75% (370 men) after a personal letter from the works medical officer. At the first interview, a brief talk was given to groups of 10 men, outlining the history of the disease in other industries and the present position in engineering. Free and, to me very informative, discussion was encouraged. A full occupational history was then taken from each employee and his skin was then examined. A particularly good light was required for the scrotal skin. A register was set up to enable men to be recalled at six-monthly or annual intervals, depending on the degree of exposure to oil. The importance of personal

hygiene and self-examination of the scrotum at approximately monthly intervals during bathing was stressed. A few men have retired since 1972 and letters have been sent to their general practitioners giving a brief account of the risks to which their patients have been exposed. This whole exercise has been carried out with entire good will on the part of the management and men and no industrial problems have been encountered due to anxiety or fear of manning particular machines.

From these examinations, 30 men were referred to consultant dermatologists after the general practitioner concerned had been informed. One case of carcinoma-in-situ of the scrotum and 10 cases of keratosis of the forearm have already been described. Two men had basal-cell carcinoma of actinic origin on their fingers. The remaining cases were made up of seborrhoeic warts, plain warts and lichen planus.

Risk factors

The unduly high incidence of scrotal epithelioma and keratoses of the forearm in this particular factory suggest that some adverse risk factors must have operated. Although the series is too small for statistical analysis, the presence of 2 brothers in it does point to a possible genetic factor. Earle (1823) and Kipling (1974) both state that scrotal cancer has occurred in a father and son.

The Registrar General places auto-setters in Social Grade III and, from correspondence with Dr M D Kipling of the Birmingham regional office of the Employment Medical Advisory Service, it would seem to be correct for his area, but Social Grade IV would be more appropriate for men in the Manchester area. From discussions with the 370 men who have been examined regularly since 1973, a composite impression has been formed of an employee in the 1950s who wore woollen underwear and 'working trousers' which were changed infrequently; who carried an oily wiper in his trouser pocket; whose opportunities for adequate washing of the genital area were limited to a 'tub-bath' once a week in front of the fire; who had no access to effective cleaning facilities for oil-soaked clothing; who 'washed off' at the end of a shift using the oil and water emulsion known as 'mystic' or 'suds'; and who finally, at the end of the day, rode home on a bicycle. Most of these factors had changed for the better by the mid-1960s.

Until recent months, the use made of effective protective clothing has been unsatisfactory. Only labourers would wear heavy oil-resistant aprons while the possibly more status-conscious setters preferred brown coat-type overalls, often unbuttoned and thus affording scant protection from the oil spray. The setter's wiper was usually carried over his left shoulder.

Detailed records of the temperatures in the machine shops are available for the past twenty-five years and Table 3 shows the average and maximum monthly temperatures of 1955 in the

Table 3. 1955 monthly temperatures in heavy chain department

	Average (°C)	Maximum (°C)
January	20.8	22.8
February	20.4	23.3
March	20.4	23.3
April	19.2	26.1
May	19.9	25.6
June	19.9	30.6
July	21.9	28.9
August	21.1	28.3
September	20.3	23.3
October	20.6	24.4
November	20.6	23.8
December	20.3	22.2

department housing most of the bar automatic lathes. The temperatures in other years show a similar pattern. In the Lancashire cotton industry, the minimum temperature required before mule spinning could start was 23.9°C (75°F), and it will be noted that the temperatures in this machine shop have frequently reached this figure. The woollen trade in Yorkshire employed mule spinners who worked in cooler conditions and scrotal cancer was unknown among these workers (Lee & McCann 1967). A high ambient temperature does appear to be an adverse factor.

An important carcinogenic role is played by polynuclear aromatic hydrocarbons (PNA) which are present in the coolants. It is first necessary to consider the possible effect of oils derived from shale, which have been known to be especially carcinogenic since the work of Twort & Twort (1931) for the Manchester Cancer Committee. Enquiries to several major British oil companies have failed to exclude the possibility that shale oil could have been used in the preparation of cutting fluids in the difficult years during and following the war until 1962 when the Scottish shale oil industry finally closed down.

Modern neat cutting oils have, since 1966, had their content of polynuclear aromatic compounds reduced by solvent refining, but little information has so far been published in this country about the possible production by prolonged use. Admittedly there is only a small area of contact between the tool tip and the workpiece involved, but physical conditions there can be extreme involving pressures of 690 000 to 3 105 000 kPa (100 000 to 450 000 lbf/in²) and temperatures between 600°C and 800°C. In the absence of any internationally-agreed threshold limit values for PNA carcinogens, it has been difficult to decide which compounds to seek, but the publication by Catchpole *et al.* (1971) describing a technique for estimating the concentration in mineral oil of the active carcinogen benzo(a)pyrene, known otherwise as 3,4-benzpyrene (BaP), pointed the way, and I have accepted the earlier view of Schoental (1964) that '3,4-benzpyrene is therefore a useful indicator of the type of compounds present in carcinogenic materials, even though it may not be responsible for all, or even the main part, of their carcinogenic activity'.

One of the main purposes of this paper is to show the possible dangers associated with the reliance upon oil reclamation plants on the factory site. These plants carry out an effective 'laundrying service' removing water and particulate matter, but cannot be expected to remove any polycyclic aromatic compounds formed during prolonged use of neat oils. Such a plant was installed in this factory in 1961 and has been in continuous use ever since. Its essential features are shown in Figure 1 and are the same as the scheme described by Eyres (1973) in a symposium held by the Institute of Petroleum as recently as 1972. No simultaneous regular changes of all the cutting oil in use at any one time were made until 1976. The oil coming from the reclamation plant contains a small amount of a stamping oil derived from centrifuging scrap metal from machines other than the automatic lathes.

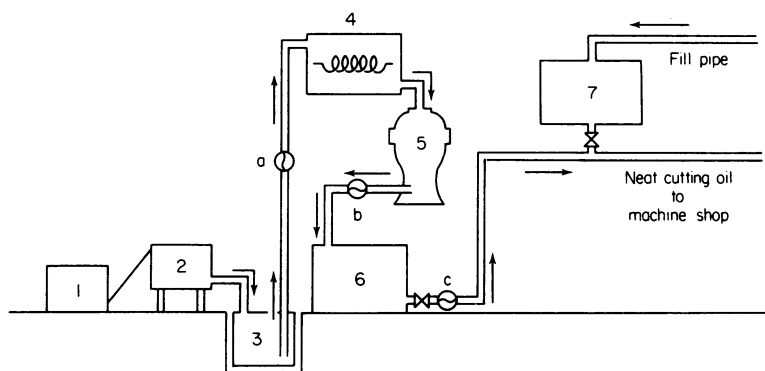


Figure 1. Diagram of oil reclamation plant. 1, swarf crusher; 2, swarf spinner; 3, collecting tank; 4, sterilizing tank; 5, oil centrifuge; 6, reclaimed oil tank; 7, new oil tank; a, b, c, pumps

Analytical results

The first series of analyses were performed by Dr R C Garner of the Cancer Research Unit, University of York, on samples of new cutting oil, used oil taken from the sump of an automatic lathe and reclaimed oil. The aromatic residues obtained were subjected to spectrophotometric and high pressure liquid chromatographic analyses. Table 4 sets out the

Table 4. Analysis of cutting oils, University of York (absorption ratios at 350/250 nm)

	OD ₃₅₀ /OD ₂₅₀	Increase ●
New oil	0.019	1.0
Used oil	0.080	4.1
Reclaimed oil	0.044	2.3

● represents factor by which aromatic content has increased

absorption ratios of the three oils. The higher this ratio is, the greater is the PNA content. The ratio OD₃₅₀/OD₂₅₀ gives a better indication of the carcinogenic content, since the tricyclic compounds do not absorb at these higher wavelengths. The chromatographic profile of the used oil is shown in Figure 2 and a small amount of BaP is present, but the main compounds are probably pyrene, chrysene, anthracene and phenanthrene. BaP was not demonstrated in the new or reclaimed oil.

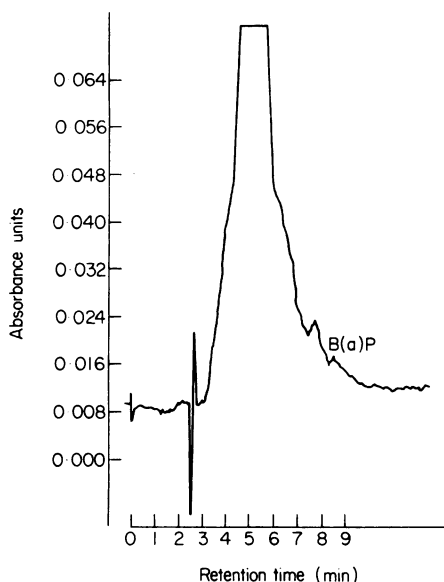


Figure 2. Chromatographic profile of used cutting oil. (Courtesy of University of York)

The second set of investigations were offered by the Occupational Health Unit, BP Research Centre, Sunbury-on-Thames. Their workers defined PCA (polycyclic aromatic hydrocarbon) 'the material eluting from chromatographic column between pyrene and perylene', i.e. PNA compounds containing between four and five rings. This must not be confused with the total aromatic content or %C_A which is used to be quoted by oil-blending companies but which is not reliable as an indicator of the carcinogenic hazard. The BP results are shown in Table 5.

Table 5. Analysis of cutting oils, BP Research Centre

	PCA (% weight)	BaP (mg/kg)
New oil	0.6	0.02
Used oil	3.8	0.11
Reclaimed oil	4.0	0.09

PCA, polycyclic aromatic hydrocarbons

BaP, benzo(a)pyrene

These values are of the same order as oils which have been tested biologically and shown to be carcinogenic. It is obvious that reclaiming the oil has not effectively reduced the PNA content.

Shell UK Oil offered the final series of analytical tests, which were performed at the Thornton Research Centre. Samples consisted of new oil, used oil taken from the collecting tank after centrifugal separation from scrap metal (*see* Figure 1) and reclaimed oil. This laboratory estimated the PNA compounds containing four and five rings, using a thin layer chromatographic method with mass spectrographic resolution (Table 6). A dimethyl sulphoxide extraction method was also used and gave similar ranking results.

Table 6. Analysis of cutting oils, Shell Thornton Research Centre

	PCA % weight (4 & 5 rings only)
New oil	0.3–0.5
Used oil	1.9
Reclaimed oil	3.4

Discussion

Although these three sets of results involved different techniques and measurements and are therefore not strictly comparable, they do, however, suggest that considerable quantities of PNA compounds do build up during prolonged use and, furthermore, that these compounds are not removed by the reclamation process. It will not be possible to repeat these investigations because a stricter control of oil changes has meant that oil which has been subjected to prolonged use and repeated reclamation will no longer be available for analysis. The frequency of oil changes will, in future, be based on current investigations using a 'dedicated' lathe, in which the concentration of PNA in its cutting oil will be monitored at two-monthly intervals by the Thornton Research Centre. Thony *et al.* (1975) from the Vallée de l'Arve, found BaP concentrations of 0–250 µg/l in fifteen samples of used oil, but BaP levels of 0–170 µg/l were also found in fifteen brands of new cutting oil.

It has not yet been possible to prove that the accelerating action of long chain aliphatic hydrocarbons, such as n-dodecane, on PNA carcinogenesis (Horton *et al.* 1966) has any relevance to cutting oils. Sims & Grover (1974) showed that PNA hydrocarbons exert their carcinogenic activity when the K-region phenanthrenoid bond is modified to an epoxide which subsequently interferes with the DNA chain, and so the above analytical results are linked to modern concepts of carcinogenesis.

During the last two hundred years, scrotal cancer has ceased to occur in the older industries and it now seems likely that newer techniques of forming metal, such as the cold extrusion process, and the wider use of totally synthetic coolants, free of mineral oil, will lead to the final disappearance of this disease from the engineering scene, although judging from the experience

in the Lancashire cotton industry, the problem of the many men already exposed to carcinogens in coolant fluids will remain for a further 25 years or more.

Summary

After reviewing its occurrence in older industries, five fatal cases and one non-fatal case of scrotal cancer, occurring in a light engineering factory from 1955–75, are described. Possible genetic factors, personal hygiene, protective clothing, prior development of keratoses on the forearms and the high ambient temperatures in a machine shop using bar automatic lathes are discussed. Results of analyses of new, used and reclaimed oils for polynuclear aromatic carcinogens in three different laboratories are given. The possibility of too-prolonged use of neat cutting oils and of conventional oil reclamation plants, leading to a dangerous accumulation of carcinogens, such as benzo(a)pyrene, is noted.

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